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Permeability of Ultra-Fine Reactive Fly Ash applied to Cement-Based Composites

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1 Introduction

Ultra-fine reactive fly ash (URFA) having very fine particles have been extracted by processing conventional fly ash, and it is becoming increasingly popular in the construction industry (Bagheri *et al.*, 2013). These fine particles often have a similar chemical composition with the conventional fly ash, but it has reduced surface area per particle. Recent research has shown that URFA exhibited better pozzolanic activity and more desirable performance in concrete than normal fly ash (Elsayed *et al.*, 2011; Duan *et al.*, 2018; Han *et al.*, 2019). When heated, micro-spheres heat up and crackle until they burst at about 260℃; their shells start to splinter at about 1100℃ and finally collapse at about 1300℃. The superfine particles obtained can then be used to partially replace Portland cement and their particulate structures. This study aims to determine its suitability as a pozzolanic additive to improve the performance of cement-based materials. Flowability, compressive strength, drying shrinkage, total charge passed, MIP analysis and SEM observations were conducted and compared.

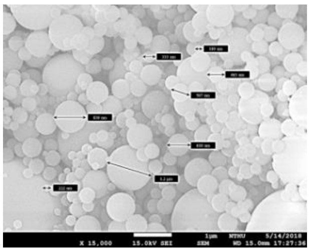

Figure 1. SEM photo of URFA.

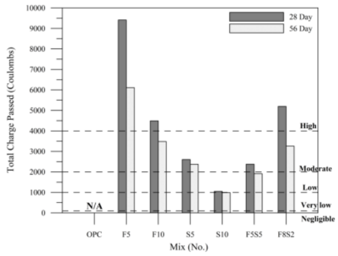

Figure 2. Total charge passed histograms.

2 Experiments

The fixed water-to-binder ratio was 0.45 and the replacement of cement was used as 5% and 10%. The combinations of URFA and silica fume in composites were used as 5% URFA plus 5% silica fume and 8% URFA plus 2% silica fume. URFA was provided by TRIAXIS Corporation from a power plant in Inner Mongolia. The specific gravity and specific surface area of URFA is 2.20 and 3380 m^2/kg, respectively. URFA has an average content of 49.11%

silicon dioxide, 28.07% aluminum oxide and 8.84% calcium oxide. The SEM photo of URFA particles is shown in Fig. 1 and the average particle size was between 0.1 µm to 10 µm.

3 Results and Discussion

The strength development trend of F10 specimens was closed to that of the S5 specimens. Compared with silica fume, URFA has a much smaller specific surface area, so it can increase bulk density without excessively increasing the total solid surface area. It is able to fill the voids in cement to increase the packing density of the cementitious materials. It has a particle size of micrometer-scale and is spherical in shape, which can improve properties in compressive strength due to the active pozzolan reaction and filling effect.

It indicated that drying shrinkage of the specimens containing URFA was lower than that of the specimens containing silica fume and control specimens. The results of rapid chloride penetration test for all mixes are illustrated in Fig. 2. The trend of F5S5 specimens is closed to that of S5 specimens due to the pore structure modification. SEM observations indicated that finer silica fume and URFA particles mixed into the specimens improved the compactness through pozzolanic reactivity and pore filling effect. It may be as mainly hydrated reaction that $Ca(OH)_2$ reacted with SiO_2 or Al_2O_3 to form C-S-H or C-A-S-H colloids. MIP test was confirmed that the finer particles of URFA were useful to the pore structure modification.

4 Conclusions

The results show that the inclusion of URFA was enhanced to increase the workability, and help to produce pozzolanic reaction and C-S-H colloids. The colloids were filling the pore structures to increase the compactness of specimen, which is consistency with the increased the compressive strength and reduction of the dry shrinkage. It also was reduced the chloride ion penetration and non-steady state migration coefficient, which is helpful for improving the mechanical properties and permeability. or blending specimen, it was also a tendency to improve mechanical properties and permeability; and the combination of 5% URFA and 5% silica fume in composites enhanced better performances.

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